

1. Work out the relative molecular masses (M_r) of the following compounds:

- a) SO_2 64.06 g/mol
 b) NH_3 17.04 g/mol
 c) $\text{Ca}(\text{NO}_3)_2$ 164.10 g/mol

2. Copy and complete the table. The first one has been done for you.

Compound	Molar Mass g mol^{-1}	Mass/ g	Number of moles/ mol
H_2O	18.02	9.01	0.500
CO_2	44.01	5.00	0.114
H_2S	34.08		0.100
Q	28.6	1.00	0.0350

3. Work out the mass of a molecule of H_2O

$$\frac{18.02 \text{ g/mol}}{6.02 \times 10^{23} \text{ molec.}} = 2.99 \times 10^{-23} \text{ g/molec.}$$

4. Work out the total number of hydrogen atoms in 0.200 mol CH_4

$$\frac{0.200 \text{ mol}}{1 \text{ mol}} \times \frac{6.02 \times 10^{23} \text{ molec.}}{1 \text{ molec.}} \times \frac{4 \text{ atoms H}}{1 \text{ molec.}} = 4.82 \times 10^{23} \text{ atoms}$$

5. Calculate the total number of atoms in 0.0400 mol $\text{C}_2\text{H}_5\text{OH}$

$$\frac{0.0400 \text{ mol}}{1 \text{ mol}} \times \frac{6.02 \times 10^{23} \text{ molec.}}{1 \text{ molec.}} \times \frac{9 \text{ atoms}}{1 \text{ molec.}} = 2.17 \times 10^{23} \text{ atoms}$$

.05 mo

6. Calculate the number of moles of oxygen atoms in 0.03 mol XeO_4

$$\frac{0.03 \text{ mol XeO}_4}{1 \text{ mol XeO}_4} \times \frac{4 \text{ mol O}}{1 \text{ mol XeO}_4} = 0.12 \text{ mol O}$$

7. Calculate the percentage by mass of oxygen in $\text{CH}_3\text{CH}_2\text{COOH}$

$$\%O = \frac{2(16.00)}{74.09} \times 100 = 43.19\%$$

8. Calculate the mass of oxygen in 6.00g of $\text{C}_3\text{H}_7\text{OH}$

$$\%O = \frac{16.00}{60.11} \times 100 = 26.62\% \quad 6.00(0.2662) = 1.60\text{g O}$$

9. For CH_3OH , work out the mass of substance that will contain 1.00g of oxygen.

$$\frac{16}{32.05} = \frac{1.00}{x} \quad x = 2.00\text{g CH}_3\text{OH}$$

10. Which of the following represent empirical formulas?

a) C_2H_4

b) CO_2

c) CH

d) HO

e) C_3H_8

f) C_4H_{10}

g) H_2O

h) H_2O_2

i) N_2H_4

j) PCl_5

k) CH_3COOH

11. Copy the table below and complete it with the molecular formulas of the compounds, given the empirical formulas and relative molecular masses.

Empirical Formula	Relative Molecular Mass	Molecular Formula
HO 18.01	$\frac{34.02}{18.01} = 2$	H_2O_2
ClO_3 83.45	$\frac{166.90}{83.45} = 2$	Cl_2O_6
CH_2 14.01	$\frac{84.18}{14.01} = 6$	C_6H_{12}
BNH_2 26.84	$\frac{80.52}{26.84} = 3$	$\text{B}_3\text{N}_3\text{H}_6$

12. Analysis of a sample of an organic compound produced the following composition:

C: 0.399g H: 0.101g

a. Calculate the empirical formula

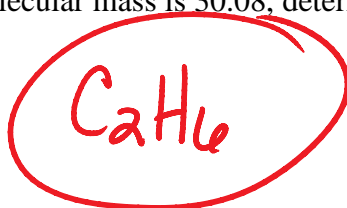
$$\frac{0.399 \text{ g C}}{12.01 \text{ g/mol}} = 0.03322 \text{ mol} / 0.03322 = 1$$

$$\frac{0.101 \text{ g H}}{1.01 \text{ g/mol}} = 0.1000 \text{ mol} / 0.03322 = 3$$



b. Given that the relative molecular mass is 30.08, determine the molecular formula

$$\frac{30.08}{15.04} = 2$$



13. If an oxide of chlorine contains 81.6% chlorine, calculate its empirical formula.

$$\frac{81.6 \text{ g Cl}}{35.45 \text{ g/mol}} = 2.30 / 1.15 = 2$$

$$\frac{18.4 \text{ g O}}{16.00 \text{ g/mol}} = 1.15 \text{ mol} / 1.15 = 1$$



14. A compound, X, contains 64.8% carbon and 13.6% hydrogen. If the only other element present is oxygen and a single molecule of the compound contains four carbon atoms, calculate the molecular formula of X.

$$\frac{64.8 \text{ g C}}{12.01 \text{ g/mol}} = 5.396 \text{ mol} / 1.35 = 4$$

$$\frac{13.6 \text{ g H}}{1.01 \text{ g/mol}} = 13.465 \text{ mol} / 1.35 = 10$$

$$\frac{21.6 \text{ g O}}{16.00 \text{ g/mol}} = 1.35 \text{ mol} / 1.35 = 1$$



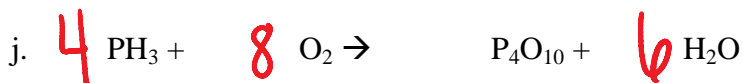
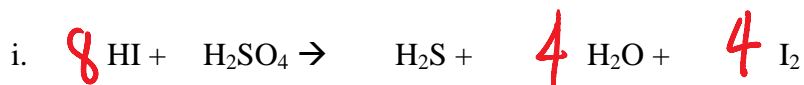
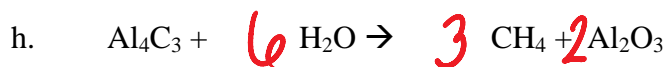
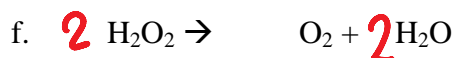
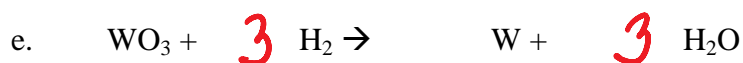
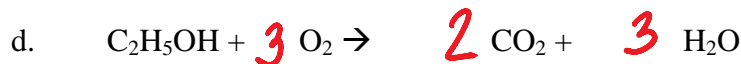
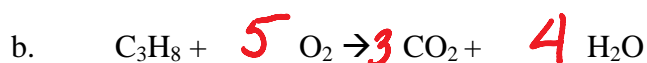
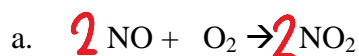
15. When 5.60g of an iron oxide is heated with carbon, 3.92g of iron is produced. Calculate the empirical formula of the iron oxide.

$$\frac{3.92\text{g Fe}}{55.85} \div \frac{1\text{mol Fe}}{55.85} = \frac{0.07019\text{mol}}{0.07019} = 1 \times 2 = 2$$

$$\frac{1.68\text{g O}}{16.00\text{g}} \div \frac{1\text{mol O}}{16.00\text{g}} = \frac{0.105\text{mol}}{0.07019} = 1.5 \times 2 = 3$$

Fe_2O_3

16. Balance the following equations:

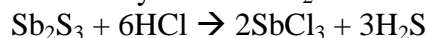


17. How many moles of hydrogen gas are produced when 0.4 moles of sodium react with excess water?



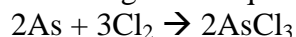
$$\frac{0.4 \text{ mol Na}}{2 \text{ mol Na}} \times \frac{1 \text{ mol H}_2}{1 \text{ mol H}_2} = 0.2 \text{ mol H}_2$$

18. How many moles of H_2S are formed when 0.02 mol of HCl react with excess Sb_2S_3 ?



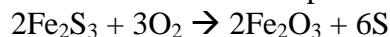
$$\frac{0.02 \text{ mol HCl}}{6 \text{ mol HCl}} \times \frac{3 \text{ mol H}_2\text{S}}{1 \text{ mol HCl}} = 0.01 \text{ mol H}_2\text{S}$$

19. Calculate the mass of arsenic(III) chloride produced when 0.150 g of arsenic reacts with excess chlorine according to the equation:



$$\frac{0.150 \text{ g As}}{74.92 \text{ g}} \times \frac{1 \text{ mol As}}{2 \text{ mol As}} \times \frac{2 \text{ mol AsCl}_3}{1 \text{ mol As}} \times \frac{132.91 \text{ g}}{1 \text{ mol AsCl}_3} = 0.363 \text{ g}$$

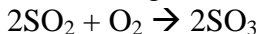
20. What mass of sulfur is produced when 5.78 g iron(III) sulfide is reacted with excess oxygen?



$$\frac{5.78 \text{ g Fe}_2\text{S}_3}{207.88 \text{ g}} \times \frac{1 \text{ mol Fe}_2\text{S}_3}{2 \text{ mol Fe}_2\text{S}_3} \times \frac{6 \text{ mol S}}{1 \text{ mol Fe}_2\text{S}_3} \times \frac{32.06 \text{ g}}{1 \text{ mol S}} = 2.67 \text{ g S}$$

21. Calculate the percentage yield in each of the following reactions.

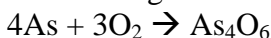
- a) When 2.50g of SO_2 is heated with excess oxygen, 2.50g of SO_3 is obtained.



$$\frac{2.50\text{g}}{64.06\text{ g}} \times \frac{1\text{mol SO}_2}{2\text{mol SO}_3} \times \frac{80.06\text{ g}}{1\text{mol SO}_3} = 3.12\text{g}$$

$$\frac{2.50\text{g}}{3.12\text{g}} \times 100 = 80.1\%$$

- b) When 10.0g of arsenic is heated in excess oxygen, 12.5g of As_4O_6 is produced.



$$\frac{10.0\text{g As}}{74.92\text{ g}} \times \frac{1\text{mol As}}{4\text{mol As}} \times \frac{395.68\text{ g}}{1\text{mol As}_4\text{O}_6} = 13.2\text{g}$$

$$\frac{12.5}{13.2} \times 100 = 94.7\%$$

22. What is the limiting reactant in each of the following reactions?

- a) 0.5 mol Sb_4O_6 reacts with 0.5 mol H_2SO_4
 $\text{Sb}_4\text{O}_6 + 6\text{H}_2\text{SO}_4 \rightarrow 2\text{Sb}_2(\text{SO}_4)_3 + 6\text{H}_2\text{O}$

$$\frac{0.5\text{ mol Sb}_4\text{O}_6}{1\text{mol Sb}_4\text{O}_6} \times \frac{2\text{mol Sb}_2(\text{SO}_4)_3}{1\text{mol Sb}_4\text{O}_6} = 1\text{mol}$$

$$\frac{0.5\text{ mol H}_2\text{SO}_4}{6\text{mol}} \times \frac{2\text{mol}}{1\text{mol}} = 0.33\text{mol}$$

H_2SO_4 LR

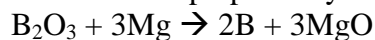
- b) 0.20 mol AsCl_3 reacts with 0.25 mol H_2O
 $4\text{AsCl}_3 + 6\text{H}_2\text{O} \rightarrow \text{As}_4\text{O}_6 + 12\text{HCl}$

$$\frac{0.20\text{ mol AsCl}_3}{4\text{mol AsCl}_3} \times \frac{1\text{mol As}_4\text{O}_6}{1\text{mol AsCl}_3} = 0.05\text{mol}$$

$$\frac{0.25\text{ mol H}_2\text{O}}{6\text{mol H}_2\text{O}} \times \frac{1\text{mol As}_4\text{O}_6}{1\text{mol H}_2\text{O}} = 0.042\text{mol}$$

H_2O
LR

23. Boron can be prepared by reacting B_2O_3 with magnesium at high temperatures:

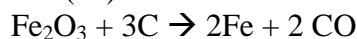


What mass of B is obtained if 0.75g B_2O_3 is reacted with 0.50g Mg?

$$\frac{0.75g B_2O_3}{69.62g} \times \frac{1mol B_2O_3}{1mol B_2O_3} \times \frac{2mol B}{1mol B_2O_3} \times \frac{10.81g}{1mol B} = 0.23g$$

$$\frac{0.50g Mg}{24.31g} \times \frac{1mol Mg}{3mol Mg} \times \frac{2mol B}{1mol B} \times \frac{10.81g}{1mol B} = 0.15g$$

24. Iron(III) oxide reacts with carbon to produce iron:



What mass of Fe is obtained if 10.0 tonnes of Fe_2O_3 is reacted with 1.00 tonne of C?

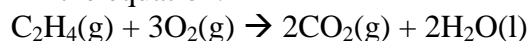
$$1 \text{ tonnes} = 1000 \text{ kg}$$

$$\frac{10.0 \text{ tonnes}}{1 \text{ tonnes}} \times \frac{1000 \text{ kg}}{1 \text{ kg}} \times \frac{1000g}{159.70g} \times \frac{1mol Fe_2O_3}{1mol Fe_2O_3} \times \frac{2mol Fe}{1mol Fe_2O_3} \times \frac{55.85g}{1mol Fe} = 7.00 \times 10^6 g$$

$$\frac{1.00 \text{ tonne}}{1 \text{ tonne}} \times \frac{1000 \text{ kg}}{1 \text{ kg}} \times \frac{1000g}{12.01g} \times \frac{1mol}{3mol C} \times \frac{2mol Fe}{1mol Fe} \times \frac{55.85g}{1mol Fe} = 3.1 \times 10^6 g$$

25. Assume that all gases behave as ideal gases and that all measurements are made under the same conditions of temperature and pressure.

a) Calculate the volume of CO_2 produced when 100 cm^3 of ethane burns in excess oxygen according to the equation:



$$\frac{100 \text{ cm}^3 C_2H_4}{1 \text{ cm}^3 C_2H_4} \times \frac{2 \text{ cm}^3 CO_2}{1 \text{ cm}^3 C_2H_4} = 200 \text{ cm}^3 CO_2$$

- b) Calculate the volume of NO produced when 2.0dm^3 of oxygen is reacted with excess ammonia according to the equation:



$$\frac{2.0\text{dm}^3\text{O}_2}{5\text{dm}^3\text{O}_2} \times \frac{4\text{dm}^3\text{NO}}{4\text{dm}^3\text{NO}} = 1.6\text{dm}^3\text{NO}$$

26. Determine the number of moles present in each of the following at standard temperature and pressure

- a. 0.240dm^3 of O_2

$$\frac{0.240\text{dm}^3\text{O}_2}{22.4\text{dm}^3} \times \frac{1\text{mol}}{1\text{mol}} = 0.0107\text{mol}$$

b. 2.00dm^3 of CH_4

$$\frac{2.00\text{dm}^3}{22.4\text{dm}^3} \times \frac{1\text{mol}}{1\text{mol}} = 0.0893\text{mol}$$

c. 0.100dm^3 of SO_2

$$\frac{0.100\text{dm}^3}{22.4\text{dm}^3} \times \frac{1\text{mol}}{1\text{mol}} = 0.00446\text{mol}$$

27. Work out the volume of each of the following at standard temperature and pressure:

a. $0.100\text{mol C}_3\text{H}_8$

$$\frac{0.100\text{mol}}{1\text{mol}} \times 22.4\text{dm}^3 = 2.24\text{dm}^3$$

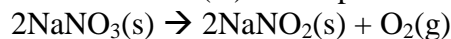
b. 100.0mol SO_3

$$\frac{100.0\text{mol}}{1\text{mol}} \times 22.4\text{dm}^3 = 2240\text{dm}^3$$

c. 0.270mol N_2

$$\frac{0.270\text{mol}}{1\text{mol}} \times 22.4\text{dm}^3 = 6.05\text{dm}^3$$

28. Sodium nitrate(V) decomposes according to the equation:



Calculate the volume (in cm^3) of oxygen produced (measured at STP) when 0.820g of sodium nitrate(V) decomposes.

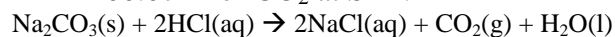
$$\frac{0.820\text{g NaNO}_3}{85.00\text{g}} \times \frac{1\text{mol NaNO}_3}{2\text{mol NaNO}_3} \times \frac{1\text{mol O}_2}{1\text{mol}} \times \frac{22.4\text{dm}^3}{1\text{dm}^3} \times \frac{10^3\text{cm}^3}{1\text{dm}^3} = 108\text{cm}^3$$

29. Tin reacts with nitric acid according to the equation:



~~omit~~

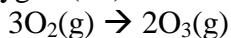
30. Calculate the mass of sodium carbonate that must be reacted with excess hydrochloric acid to produce 100.0cm^3 of CO_2 at STP.



$$\frac{100.0\text{dm}^3\text{CO}_2}{22.4\text{dm}^3} \times \frac{1\text{mol CO}_2}{1\text{mol CO}_2} \times \frac{1\text{mol Na}_2\text{CO}_3}{1\text{mol}} \times \frac{105.99\text{g}}{1\text{mol Na}_2\text{CO}_3} = 0.4732\text{g}$$

31. Assume that all gases behave as ideal gases and that all measurements are made under the same conditions of temperature and pressure.

a) Oxygen (O_2) can be converted to ozone (O_3) by passing it through a silent electric discharge.



If 300cm^3 of oxygen is used and 10% of the oxygen is converted to ozone, calculate the total volume of gas present at the end of the experiment.

$$300\text{cm}^3 \times 0.10 = 30\text{cm}^3$$

$$\frac{30\text{cm}^3 O_2}{3\text{cm}^3 O_2} \times \frac{2\text{cm}^3 O_3}{3\text{cm}^3 O_2} = \frac{20\text{cm}^3 O_3}{1.0 \times 10^5} + \frac{270\text{cm}^3 O_2}{1.0 \times 10^5} = 290\text{cm}^3$$

32. If a certain mass of an ideal gas occupies 20.0cm^3 at 0°C and $1.01 \times 10^5\text{ Pa}$, what volume would it occupy at 38°C and $1.06 \times 10^5\text{ Pa}$?

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} = \frac{1.01 \times 10^5 \text{ Pa} \times 20.0 \text{ cm}^3 \times 311 \text{ K}}{1.06 \times 10^5 \text{ Pa} \times 273 \text{ K}} = 21.7 \text{ cm}^3$$

33. A certain mass of an ideal gas occupies 250.0cm^3 at 20°C and $9.89 \times 10^4\text{ Pa}$. At what temperature (in $^\circ\text{C}$) will it occupy 400.0cm^3 if the pressure remains the same?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad T_2 = \frac{V_2 T_1}{V_1} = \frac{400.0 \text{ cm}^3 \times 293 \text{ K}}{250.0 \text{ cm}^3} = 469 \text{ K} - 273 = 196^\circ\text{C}$$

34. How many moles of an ideal gas are present in a container if it occupies a volume of 1.50dm^3 at a pressure of $1.10 \times 10^5\text{ Pa}$ and a temperature of 30°C ?

$$n = \frac{PV}{RT} = \frac{1.10 \times 10^5 \text{ kg m s}^{-2}}{\text{m s}^{-2}} \times \frac{1.50 \text{ dm}^3}{10^{-3} \text{ m}^3} \times \frac{1}{8.31 \text{ kg m}^2 \text{ s}^{-2} \text{ mol}^{-1} \text{ K}^{-1} \times 303 \text{ K}} = 0.0655 \text{ mol}$$

35. Calculate the molar mass of an ideal gas if 0.586g of the gas occupies a volume of 282cm^3 at a pressure of $1.02 \times 10^5\text{ Pa}$ and a temperature of -18°C .

$$M = \frac{gRT}{PV} = \frac{0.586 \text{ g}}{\text{mol}} \times \frac{8.31 \text{ J mol}^{-1} \text{ K}^{-1}}{\text{Pa}} \times \frac{255 \text{ K}}{1.02 \times 10^5 \text{ Pa}} \times \frac{1 \text{ m}^3}{10^{-3} \text{ dm}^3} = 43.2 \text{ g/mol}$$

36. What is the molar volume of an ideal gas at $1.10 \times 10^5 \text{ Pa}$ and 100°C .

$$PV = nRT$$

$$\frac{V}{n} = \frac{RT}{P} = \frac{8.31 \text{ J mol}^{-1} \text{ K}^{-1}}{\text{Pa}} \times \frac{373 \text{ K}}{1.10 \times 10^5 \text{ Pa}} \times \frac{1 \text{ m}^3}{10^{-3} \text{ dm}^3} = 28.2 \text{ dm}^3 \text{ mol}^{-1}$$